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CLASSIFICATION

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

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PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs \$2, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

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fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $P_{\mathbf{c}}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the $_{
m 30}$ yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 Sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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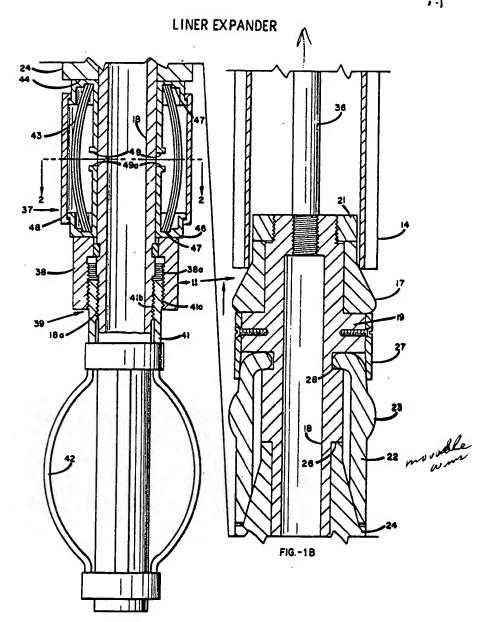
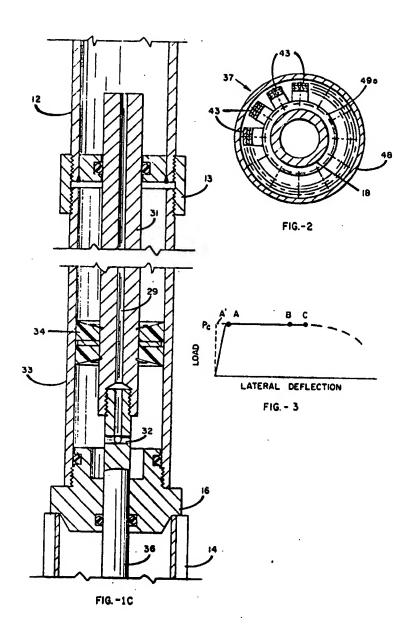


FIG.-1A



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2. A. A device for expending a metallic line; inside a conduct which
2 device comprises a shaft almost, on expanding the member obtained to easi
3 shaft closest, said die member comprising a movable liner-forming member
4 positioned on easis shaft and being carially movable in respect thereof to
5 contact said liner, as expander member alidably positioned on said shaft
6 between said shaft and said die member to move said liner-forming member
7 from said shaft, and a constant force spring number positioned on said staft
8 to contact said expander member and to maintain said expenser member against
9 said liner-forming member, charaty said liner-forming member is unjud against
10 said liner for a substantially constant force.

2. In a device for installing an extended setablic liner in a conduct wherein an expanding site is moved through a liner positional in said wonder to words mid liners a cylindrical short alamen, an expanding site massher attached to said short, said site newtor comprising a plurality of arm numbers disposed around said short and being pivotable extensity therefrom to contact said liner, a cone member slidebly positioned on said short between said short and said are members to very said are members colouredly from said short, and a constant force opring number positioned on said starts to contact said ones member and to maintain said come number in contact with said are numbers, whereig said top tenture are urged outpartly by a sobstantially constant force.

J. The Series of Claim 2 stanceds said constant force operag content
comprises a planning of orderes disposed accord said shaft, a steet bearing
plate center and a second bearing plate scatter, each of said bearing plate
members contenting opposite citie of said columns, at least one of said tearing
plate numbers being severally positioned on said shaft and being in contact
the said come number, stop means connected to said start to limit the actal
traval of said newhole bearing plate number along said shaft, and compression
memos for unintaining a literal deployation is said columns.

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- 4. The device of Claim 3 wherein said congression group comprises a differential sures connecting min agring number and said shaft.
- 5. The duries of Chain 3 wherein said step seems comprises a sleave-like elevent somestod to said movehile tearing plate meter and stream positiones on sale short and a sushor currently to sale staff to limit the terms of asia slows-like element.
- 6. The dovice of Chain 3 whereis soid columns have a mentragular eross-sortion, the width being greater than the Mickeys, and banks the vider fury award to the disenter of maid shaft.
- 7. A device for installing at expended astallis liner in a comissis th comprises a sylindrical sheft classic; on ampending dis number sounded on mid shaft, said she senter comprising a plantity of are senters disposed ciremeteruntially around the outside of said shaft and being pluotable outearth) therefrom to contact the limer; a scalest expending maker alidably positioned on said short between said short and mad are scalars to says said mbers outstably from suid sheft; a plurality of siencer columns, cash baving a long restangular cross-sertion and disposed sireasterentially shout sold chaft; an upper bearing plate moder and a lower tearing plate scatter, each slidely positioned on said shaft and conducting opposite onds of said columns; limiting alseves ubtended to each of said bearing plate numbers and although positioned an acid staft; a shoulder number on such shaft; a differential sensy almost connecting will shoulder and said shoth to apply sting look to said enisumes unid thoulear being transposite with the limiting shares semected to said looks bearing plate mester, wherety the axial travel of said bearing plate members is limited; said column numbers brancestring their bunking look to eath arm numbers to urgs said arm grobers 18 outserfly with a substantially constant force.

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My invention will be better understood by reference to the following description and the assumptnying drawings wherein:

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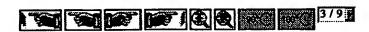


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Figure 2 to a sectional view of the apparatus of Figure 14 tabso at

Figure 3 is a typical plot of applied lock versus Deflection for the constent force spring device of the Levestica.

Referring to the drawings, Figure 15 is the bottom portion of a liser expending book for one in installing a metallic liner in a well, while Pigure 13 tilmetrates the middle section of such a tool and Figure 10 represents the upper section of the tool. The expending tool il is attached to stantard well taking 15 by ampling 15 out, typically, may be lessred from the surface through a well easing (not shown) to a point in the saving at which it is sectred to install a metallic liner. Defore inserting the tool into the well, as alcounted vertically excrepted timer in fabricated from alid steel, or other suitable mileshie meterial, is placed on the tool. The corrupted liner is occured in position by centart at its upper end with a cylindrical shoulder master 16 and, at the lover and by contact with a first-stage expansing dis 17 in the form of a troncated circular pore which serves as a firstrings expending die in the survey bareinefter described. The expending die is fixedly edtached to a controlly located, elemented cylintrical ballow shaft 18which forms a portion of the body of the tool. As shows, the expending \$10 17 is held in place between a lower shoulder 19 and coller 21 threaded onto the short. . A plurality of movehic erim 89, presently provided with outwardly cularged portions 25 sear the top; are disposed in the form of a sylindar around sharts 18. The enlarged purbloss of the eras 25 upon being moved outvarily contact the liner to perform the final step of expending the sucregated ... liner into a embetantially sylintrical chaps. The are seahers H2 are pivotally etterhod to the shaft so as to be moveble outwardly from the shaft by a tapared expanding member 26 slidebly positioned on the about to source as a second-stage expender. The series of the medict 2h, as shown, moves specially along the shaft to sugage with the arms and more them outwerfly. Advantageously, the 30 inside surfaces of the area 22 and the outside surface of expending member 24 form meting sestions, typically nategoral is shape. The expension of the era abore is comiralled by the position of the master St raich moves upwarfly



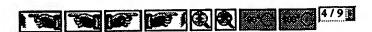
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much it contacts shoulder 26 provided on the claft. As member 24 moves in a domestily direction area 22 feld invertily towers the shaft. The expending area 22 are held to place on the shaft by collect 27 and circular grooms 20

The expending tonl, comprising the first-stage die and the seather stage die is dress through the liner to expend to the place in the casing. The first-stage die prevides a gross differention of the liner so that it is expended outwordly against the well of the ensing. The second-stage die them passes through the liner and performs the fibel expension to except the inner services of the liner and to provide more even contact between the liner and the well of the casing and effect a finid-tight seal.

In operation, the liner setting tool is essembled at the surface, so described shore, and a glass sloth saturated with a reviscous material only be erapped around the corrugated into to form the liner. The assembly is lovered into the wall at the location at which the liner is to be set. A liquid, such so cil, is then people under presence down the wall tubing and flows through the percentage 29 provides to polished rot 31, through parts 52 and into epitader 35 consected to the upper and or the shoulder 16. Upon the application of finid provides to the cylinder, the piston 34 secured to polished red 31 moves upwertly in sylinder 35. As shown, rot 36 conserve polished rot 31 and shaft 15 spon shigh is mounted the first-stage expanding die 17. Then the piston \$4 moves moverally through the splindar 33 the expanding die 17 and the secondstage die 22 are draws upwardly into the accregated liner 18 and "iron out" the corregations in the liner, so that the expended liner may contect the inside well of the casing in which it is being installed. Positioned on the shaft below the expending menter th is a communitative spring menter of which is employed to mrgs the expanding number against the explaning some 22 with a substantially sometant furce. The force exacted against the arm nesters being substantially sometant, the force transmitted through the are assets to the lists and to the during will be substantially-accordant so that either shielding of the tool in the casing or regime of the casing is precluded. Or course, the chroe provided by the spring member is preselected so that the frictional



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forces between the tool and the liner and the presence exacted detent the exing are estimated at presentations and levels. The constant force spring maker example that the coverant presence between the liner founding portion 23 of the sons EZ is great enough to provide the fortred deformation of the obstion, while presenting demons to the saming or to the tool.

The speakent force spring easter 77 is alidebly mounted on the shart 18 and hald between the expending element 20 and a sylindrical lower chealder ing a portion of a differential occur almost 39 which betweents member \$1 provided with threads \$1s and \$1b us the certain and the inside, Marair, to ungage with threads on the shaft and the shoulder. The two perse, such as square, modified equare, or Acme threads, nd very high loads and differ in pitch so that anougher 35 is seven specify on the shart in when the shart is revolved relative to thinkle \$1. or 38 is secured to the short 18 by splines 45 so that it can slide to the lower and of the thinkle to a friction member, such as how aprings 42, sally estuated frintion pas, or other such device for frietlessally tegings elicit the ionide wall of the eacquit to occurs the thinkle against spect to the shuft. Frederikly, the direction of the shoulder is, and the pitch, or land, of threads like is slightly greater to threads Ma, with the pitch rotte being slove to unity. In this . wise revolution of the shaft relative to the thinkle w r 38 to edvance uppert alightly and a congression load to exerted upwardly on spring element 37 to come buckling. For example, one settlefactory res was made up using five and one-half threads/inch aquare e a shart approximately 1.7-inch outside disseter and five and three ers thronds/isch equare threads on a shoulder approximately 2.5-inches





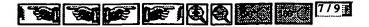
Constant force spring element 31 comprises unline element \$3, structured community constitutes of a plurality of alongsied columns structed around short 18. Upper bearing plate number \$4 in its contact with the apper ends of the salume and is althably positioned on shart 18 to truncate the force of the spring longitationally against the bottom and of expenden senter \$4. Lower bearing plate member \$6 contacts the lower mais of the columns and is noved quenchly along the saart by lengthedization invested of lower smoulder \$8 on a result of revolving differential meror element \$9. Greeves \$7 are provided in saab of the bearing plates, to form an upper race and a lower race, into which the code of the columns are inserted. These greeves may be absent to contern with the shape of the notions under it saatred. A cover \$8 any be employed to amolishe forwign matter from the spring methenium and to protect

A means for limiting the deflection of the columns to required. Although the column element functions in a buckled condition, application of . specialise accordances losd thereto would seeme total failure or reptare of the sa. Therefore, a pair of stope by end bye are provided for this purpose. As shown, the stope are rigidly commuted to the bearing plates, and, in effect comprise upper and lower limiting sleaves positioned on the shaft to alide longitudinally thereon. The ends of the stops my some toward, or sun; from, each other so the look in the spring number verter. Liver sleeve age sted from speling down by laster shoulder 36 assessed to the short 18. or, the spacing between the ends in much as to limit the longitudinal al of the bearing plats maders on they move together to prevent personal deformation of the column almost \$7. Tarious alternative mame for preing damage to the column element may also be employed. For example, plas or rings sometad on the shaft may serve as stops, or the cover 48 provided with suitable connections may be amployed for this purpose to limit longitudinal and/or lateral seflection of coinson.

The columns of the column classest 45 may be arranged erosed the chart 18, which as shown here forces a portion of the body of the spring deriver, with sucks of the columns fitted in the recess \$7. The solumns may be

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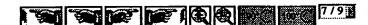
ritted closely together as shown, or may be spared around the race, with separators used between them to maintain the desired sparing. The resolut of columns seplayed will depend upon column descendants and the maintain of construction. For example, the standarders rubto of the column may be extist widely, and the column column may be retained widely, and the column column may be retained with the same and are thinged. The preferred construction is a thin, element column with toursest exist, free to now within the races should to the covarions of the column column. Naturals which may be astisfaviority amployed for the column and a deal. Naturals which may be destinabled by the same of the column and include a properly amployed for the column are one long standards properlies. September and other similar materials providing actificatory unchanical properties. Typically, the individual columns are or long statements cross-section, with the wider take of the columns is normal to the dimentar of the shart. Thus, with sufficient consponentian londing, the columns backle, and tend shout the saint having the loast someth of limiting, our property of limiting, o.g., outwardly says from the shart 15.

For exemple, a group of columns 0.167-inch thick by 0.838-inch wide by 10.626-inches long, with the ends rounded, were februard from 1.6.8.1 1340 steel, quenched and draws at 775°F. Buch column was found to require a critical compression leading of 950 pounds in order to buckle the enture.

After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure J, theretis P₀ is the critical buckling load and point 0 represents the load and deflection at which the stress is the extreme fibers of the column exceed the yield point of the untertal. Theoretically, the shape of this spring obsracteristic curve is described by curve 04'480. Actually, this curve is described by CAIO due to friction in the system. Forten A and 3 represent typical screing limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flaxing splea are not solicitated, a vertical attrees just below the stress may be held to less than the enthrence that of the material of sometimes.

To the abrenchmentical beats, the largest defication was limited to

- 7 -





approximately one inch, at which the longitudinal deflortion was approximately 0.225 inches. From more deflection to the assisted deflection, the \$50-pound loading was found to be substantially constant.

In emother test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 youds. The interal deflection was limited between 0 and about 1.00 inches by exprogrately positioning the steps. Upon compressional loading, the spring element buckled at schemantally 25,000 pounds and from a longitudinal deflexation of 0.05 inches (making) to stoom 0.15 inches the load remained substantially at 25,000 bounds.

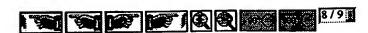
Of course, in conjusing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and articles buckling load, while uninteting the stress level in the columns at a cafe level. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with multiple flat analysis and the columns of the columns.

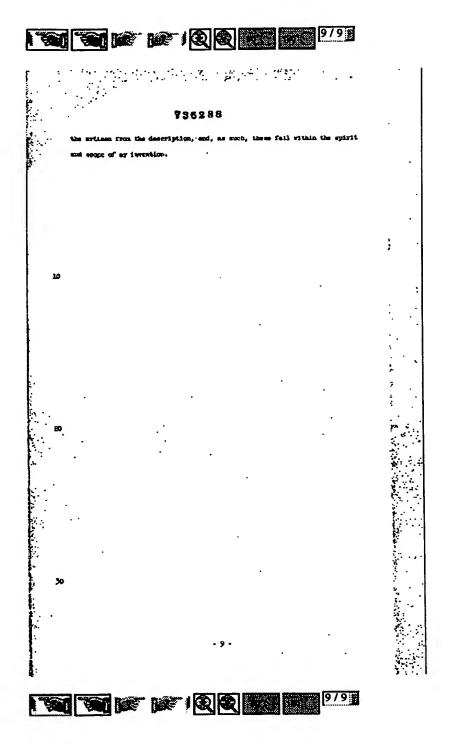
In the operation of the show capseling tool for setting a liner in well making, the medo-up tool is lowered into the well as mestioned above, with the area 22 in the retreated position. Seen the tool is at the desired level, the scaling one prevented. The friction matter by capages with the wall of the making one prevented. The friction matter by capages with the wall of the making one prevented. From revolving. But a several revolutions of the twitted, lower shoulder 35 in novel apendally by differential series 39 to bushle spring element 37 which has a predeterminal critical buckling load. This lead is transmitted upwardly against the lower set of expender 26, and its theorem surface is angaged with the tayonal surface on the incide of the orne 22 to argo the lane estimately with a substantially constant force proportional to the critical buckling load of the spring element. Estemporally, the expending tool is passed through the liner to expend it in the caping in the matter described hereinlessore.

The foregring description of a preferred embeliant of my invention.

Les here gives for the purpose of examplification. It will be understood that various mathifications in the drietle of construction will become apparent to

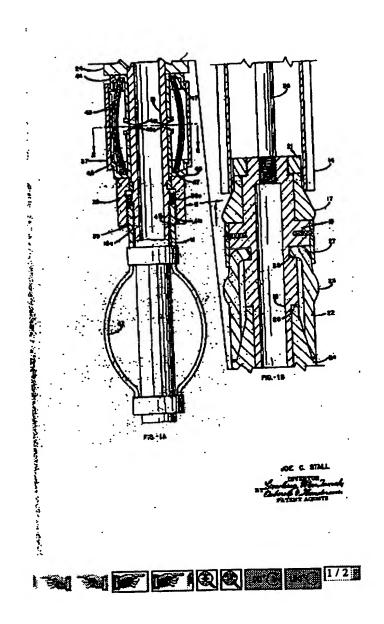
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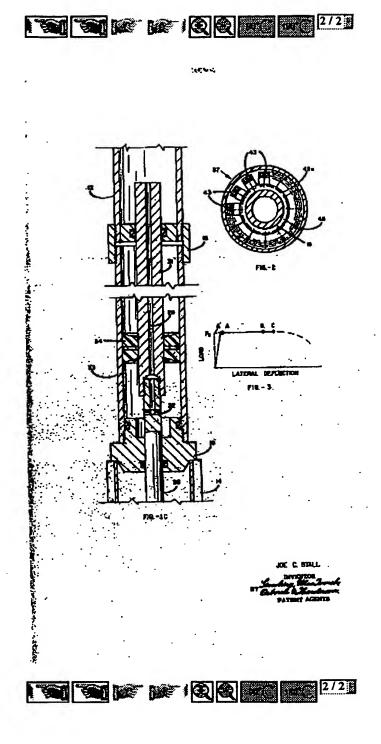






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